TEXAS DEPARTMENT OF TRANSPORTATION

BRIDGE REPLACEMENT: ALTERNATE DESIGN

by
B. R. Lindley
Assistant District Engineer
District 8
A money and time saving innovative design was used to convert two old slab bridges into multipipe culverts on an FM 18 widening project in District 8 (Abilene). Hydraulic analysis indicated that the existing structures had been overdesigned and that conversion to culverts would still meet design specifications for a hundred-year flood. Increased bearing and higher load capacity yielded by the design could easily handle the predicted future AADT.

The conversion was made by placing pipes under the bridge. The pipes were the length the proposed widening was to be. Special head and wingwall forms were designed and constructed to enclose the exposed pipe ends. Flowable fill, a freely flowing grout mix containing fly ash, was used to fill up the spaces between the existing bridge and the inserted pipes.

This design enabled the district to stay within program funds, carry existing traffic on the roadway without a detour, and produce a sound hydraulically effective structure.
PROBLEM STATEMENT

FM 18 was programmed to be reconstructed from SH 36 in Taylor County to FM 604 in Callahan County, control section 6-10-4, etc. The program estimate was based on widening two bridges that were in place on this project.

In the plan development stage, it was learned that the existing structures were not adequate to be widened. The Bridge Division advised our designers to remove and replace these structures instead of widening them.

To carry traffic on this new design would entail the building of detours at both locations. Because there is a railroad adjacent to our right-of-way on the north, the traffic could not be split in these areas so a two-way detour would have to be constructed on the south side of the right-of-way. To do this, additional right-of-way would have to be purchased or a temporary easement secured. It appeared that the temporary easement would be our only choice.

Estimates were prepared for this approach to the problem. The remove and replace items would exceed our program funds so we had to come up with another solution, request more funds, finance from other programs or not do the project at all. The last three options were not appropriate for our needs. We elected to come up with a new solution.

PURPOSE

The purpose of this experiment was to develop a design that would enable us to (a) stay within program funds, (b) carry existing traffic on the roadway without a detour, (c) produce a structurally sound structure, and (d) design a hydraulically effective structure.
DESIGN CONCEPT

The first approach that was considered was to use large pipes in lieu of a bridge-type structure. A pipe installation would work economically and hydraulically but there would still be a large expense in building the detours and removing the old structure.

It occurred to us that there could be a way to insert large pipes through the existing 10-foot spans and still have enough hydraulic capacity to carry the design water flow. If this worked out, there would still have to be a method or design to fill the void between the pipe insert and the existing bridge wall.

The original plan was to design a grout mix that would flow freely and fill the voids between the two structures. This idea was based on a grout mixture that had been used occasionally to fill voids under riprap and approach slabs. This idea led to the concept of a flowable fill.

The pipe inserts were longer than the existing bridges because our intent was to widen the existing facility. Because of these longer inserts and a need for each end to be closed, we designed special headwalls and wingwalls. These designs were exactly like any other headwall and wingwall design for metal pipe, except they were for 8-foot diameter pipes and arch design 15-foot pipes.

All other features of the design were standard and usual. Consideration was given to the type bedding for the proposed pipe. We opted to simply grade the flow line in the same manner as any other pipe installation.

This completed our design concept, and it was submitted to D-5 and was approved.
HYDRAULIC CONSIDERATIONS

A hydraulic analysis was made of the existing structures. There were two possible conclusions: either the drainage areas had changed over the years; or the original structures had been overdesigned. Whichever was the case, it does not matter because the overdesign of the existing structure gave us the latitude of reducing the area of opening. Had the existing structures been underdesigned, this design would probably have had to have been cancelled. Hydraulic analysis (next page) indicated that these two structures would meet design specifications for a hundred-year flood. Since this is a Farm-to-Market Highway, our design was more than ample.

FIGURE 3: Eight-foot Diameter Pipe.
**FM 18 Taylor and Nolan Counties, etc.**  
**CRP 90(82)S**  
**6-10-4, etc.**

### ACTUAL COST

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Price ($)</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainey Creek Sta. 100+98.8 Taylor County</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0421001037 C1 A Conc (Cuiv)</td>
<td>101.12 CY</td>
<td>400.00 CY</td>
<td>$40,448.00</td>
</tr>
<tr>
<td>0432008 Riprap</td>
<td>8.55 CY</td>
<td>195.00 CY</td>
<td>$1,667.25</td>
</tr>
<tr>
<td>0460090005 CMP (Gal Stl 96 In)</td>
<td>460.00 LF</td>
<td>90.00 LF</td>
<td>$41,400.00</td>
</tr>
<tr>
<td>8027001 Flowable Backfill</td>
<td>453.47 CY</td>
<td>10.00 CY*</td>
<td>$4,534.70</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>$88,049.95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Price ($)</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armstrong Creek Sta. 144+44.95 Callahan County</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0421001037 C1 A Conc (Cuiv)</td>
<td>67.04 CY</td>
<td>400.00 CY</td>
<td>$28,816.00</td>
</tr>
<tr>
<td>0432008 Riprap</td>
<td>3.13 CY</td>
<td>195.00 CY</td>
<td>$610.35</td>
</tr>
<tr>
<td>0460082005 CMP Ar (Gal Stl Des 15)</td>
<td>368.00 LF</td>
<td>100.00 LF</td>
<td>$36,800.00</td>
</tr>
<tr>
<td>8027001 Flowable Backfill</td>
<td>264.00 CY</td>
<td>10.00 CY*</td>
<td>$2,640.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>$66,866.35</td>
</tr>
</tbody>
</table>

*717.47 CY @ $45.00 CY additional to compensate for unbalanced bid. $32,286.15

Total Actual Cost for Two Bridges $187,202.45
**BENEFITS**

Actual cost of this installation and estimated cost for removing and replacing the two bridges are enclosed.

Note that our final cost reduction is fifty-one percent less than the standard design. This is a substantial savings that should not be overlooked, especially in terms of the tremendous savings that it could mean statewide on the “on-and off-system” designs.

There are other savings that cannot be defined in terms of dollar values, for instance the safety factor. All detours are hazardous to some extent. Anytime traffic is moved from its original path, there is a potential problem, especially in bad weather. The ability to move traffic through a project swiftly is always an asset.

The added strength of this type design is of some value. Consider the fact that the original structure was carrying the load without difficulty and the CGM pipe inserts are designed to carry the load also. Closing the void between these two structures will double the load carrying capacity.

FM 18 Taylor and Nolan Counties, etc.
CRP 90(82)S
6-10-4, etc.

**ESTIMATED COST**

**REMOVE EXISTING STRUCTURE AND REPLACE WITH COMPARABLE NEW STRUCTURE**

<table>
<thead>
<tr>
<th>Str #</th>
<th>Existing</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>#56</td>
<td>10-10' slab spans.</td>
<td>10-10'X10' MBC</td>
</tr>
<tr>
<td>#39</td>
<td>8-10' slab spans.</td>
<td>8-10'X10' MBC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Quantity</th>
<th>Price ($)</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>421</td>
<td>C1 A Conc</td>
<td>693 CY</td>
<td>400.00 CY</td>
<td>277,200.00</td>
</tr>
<tr>
<td>508</td>
<td>Construction Detours</td>
<td>2 CY</td>
<td>2,800.00 EA</td>
<td>56,000.00</td>
</tr>
<tr>
<td>496</td>
<td>Remove Old Structure</td>
<td>2 CY</td>
<td>1,500.00 EA</td>
<td>30,000.00</td>
</tr>
<tr>
<td>502</td>
<td>Barricade Sign &amp; Traffic</td>
<td>3 MO</td>
<td>6,000.00 MO</td>
<td>18,000.00</td>
</tr>
</tbody>
</table>

Total Actual Cost for Two Bridges 381,200.00
CRITICAL CONSTRUCTION FACTORS

FLOWABLE FILL – The use of fly ash in this mixture is extremely important. This material is very unusual in that it takes a lot of water for it to flow. Notice in the design specifications that it calls for 55 gallons for a cubic yard. If you exclude fly ash from the design, this material will separate and the aggregate will fall out and the water and cement will flow. Fine “blow sand” will not work, even with fly ash, because the sand will not remain in suspension.

The aggregate does not have to be clean and in most cases a waste gravel sand will perform extremely well.

The best test for segregation that was discovered was to mix a three or four-gallon batch and pour it from one container to another, letting it fall three or four feet. If the aggregate stays in suspension, the mix will probably flow very well; however, if the liquid remains on the top and all aggregate particles sink to the bottom, then a change should be made.

Flowable fill has very little flexible strength, but it is dense and void free.

HOLDING PIPE IN PLACE – The contractor on this project leveled the flow line to grade and poured a narrow concrete pad for the pipe to rest on. It was concave to fit the pipe exactly so that it would not roll from the designed position. The concrete pad was nonreinforced and only served to hold the pipe in place.

He also used concrete blocks between the existing structure and the pipe to keep the pipe from “floating” when the flowable fill is placed. If this is not done, the pipe will move around, even though both ends are poured in the concrete headwalls.

On large pipes, it is advisable to place the flowable fill at intervals. It is not advisable to pour all the fill at one time. This large pipe was poured over a period of several days.

PLACEMENT HOLES – Since it is almost forty-five feet across this structure, the contractor cut holes in the concrete deck to funnel the flowable fill into the box from the center of the structure. This shortened the flow distance as well as ensured that the center part of the structure was completely filled.

A hole is cut through the deck and a funnel placed in the hole so that the material will flow directly from the truck into the void area.

CURING TIME – Very little free water rises to the top but small (1-inch) weep holes should be drilled in end forms for water to go through. They have to be plugged as the fill rises to keep from losing the flowable fill.

If equipment is going to place base material or other materials over the top of the fill, there should be three or four days of curing time. When the material dries, it will not tear out very easily, but when it is wet, it has very little strength and will crumble easily.
Visual inspection should be used to determine when the material is set enough to handle backfilling operations.

![Flowable Fill Placement](image)

**FIGURE 4: Flowable Fill Placement**

**CONCLUSION**

The conversion procedure of the bridge to a culvert proved to be relatively simple, and everything worked as planned. The structures have a pleasing appearance and are functioning very well. There is no evidence that the existing structures are still there, and to the casual observer, this is a simple multiple pipe installation.

Metal pipe is manufactured in many sizes and the pipe companies are very anxious to custom fit any design. If the design warrants, the pipe sleeves can be used in many places, regardless of the size.

Flowable fill has proven to be a very useful tool in this design and has many other applications. It has been used as backfill material in open trenches, to fill voids under riprap, to fill erosion under approach slabs and bridge abutments, and many other places.

This application may play a very important role in our Off-System Bridge Replacement Program. Many counties have a hard time paying their twenty percent of the bridge cost under our standard design system. This design may relieve that burden or may permit more replacements in each county.
FIGURE 5: Flowable Fill Placement

FIGURE 6: Placement holes.
SPECIAL SPECIFICATION
ITEM 8027
FLOWABLE BACKFILL

8027.1. DESCRIPTION. This Item shall govern for the backfilling of structures and pipe on this project. It may be used as backfill between pipe inserts and existing concrete walls, as backfill of new culverts in lieu of soil backfill, as fill in abandoned structures, and other uses as approved by the engineer.

The flowable backfill shall be composed of Portland cement, fly ash, fine aggregate, water, and a shrinkage compensator, proportioned as hereinafter provided or an acceptable mix as approved by the engineer.

8027.2. MATERIALS.

(1) Cement. The cement shall be either Type I or II Portland cement conforming to the Item, “Hydraulic Cement”.


Type B fly ash shall not be used when Type II cement is used.

(3) Fine Aggregate. Fine aggregate shall consist of clean, hard, durable and uncoated particles of natural or manufactured sand or a combination thereof, with or without a mineral filler. It shall be free from frozen materials or injurious amounts of salt, alkali, vegetable matter of other objectionable material. When subjected to the color test for organic impurities (Test Method TEX-408-A), it shall not show a color darker than standard.

It is intended the fine aggregate to be fine enough to stay in suspension in the mortar to the extent required for proper flow. When tested by Test Method TEX-200-F, the fine aggregate shall conform to the following grading:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4 inch</td>
<td>100</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-10</td>
</tr>
</tbody>
</table>
The engineer reserves the right to reject the sand if a flowable mixture cannot be produced.

(4) Mixing Water. Water used shall be free from oils, acids, organic matter of other deleterious substances and shall not contain more than 1000 parts per million of chlorides as Cl nor more than 1000 parts per million of sulfates as SO4.

Water from municipal supplies approved by the State Health Department will not require testing, but water from other sources must be approved by the engineer prior to use.

8027.3. MIX DESIGN. The following is given as a typical mix design for trial mixes. Adjustments of the proportions of fine aggregate and/or water may be made to achieve proper solid suspension and optimum flowability with the approval of the engineer. The mix design shall contain a shrinkage compensator as approved by the engineer.

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>100 lbs.</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>250 lbs.</td>
</tr>
<tr>
<td>Fine Aggregate</td>
<td>2,990 lbs.</td>
</tr>
<tr>
<td>Water (approx.)</td>
<td>55 gal.</td>
</tr>
</tbody>
</table>

In addition, the mix design shall contain a shrinkage compensator in proportions as recommended by the manufacturer.

8027.4. CONSISTENCY. Consistency shall be tested by filling an open ended three-inch diameter cylinder six inches high to the top with flowable fill. The cylinder shall be immediately pulled straight up and the correct consistency of the flowable fill shall produce a minimum eight inch diameter circular-type spread with no segregation.

8027.5. CONSTRUCTION METHODS. As detailed in the plans, the general procedure will be to plug open ends as shown in plan details. The contractor will be required to submit a plan for approval of the engineer. He must provide a means of filling the entire void area and be able to demonstrate that this has been accomplished. This must be done without the use of a vibrator. Any inspection holes will be patched after completion and treated accordingly. Care will be taken to prevent the movement of the insert structure from its designed location. If voids are found in the fill or if any of the requirements are not met as shown on the plans, it will be the contractors responsibility to remove and replace or correct the problem without additional cost to the state.
8027.6. **MEASUREMENT.** Flowable backfill will be measured by the cubic yard based on plan quantities, adequate calculations have been made in accordance with Article 9.1. If no adjustment is required under "Payment" described below, additional measurements or calculations will not be required.

8027.7. **PAYMENT.** Flowable backfill quantity, measured as provided above, will be paid for at the unit price bid per cubic yard, which shall be full compensation for furnishing, hauling, and placing all materials and for all tools, labor, equipment, and incidentals necessary to complete the work. The quantity to be paid for will be that quantity shown on the contract plans and in the proposal, regardless of errors in calculations, except as may be modified by the following:

Plan quantities will be adjusted:

1. When a complete structure element has been erroneously included or omitted from the plans, the quantity shown on the plans for that element will be added to or deducted from the plan quantity and included for payment. A complete structure element will be the smallest portion of a total structure for which a quantity is included on the plans.
2. When the plan quantity for a complete structure element is in error by 5 percent or more, a recalculation will be made and the corrected quantity included for payment.
3. When quantities are revised by a change in design the plan quantity will be increased or decreased by the amount involved in the design change.

FIGURE 7: Forms at Side of New Headwalls
The party to the contract requesting the adjustment shall present to the other, three copies of the description and location, together with calculations of the quantity for the structure element involved. When this quantity is certified correct by the engineer, it will become the revised plan quantity.
GENERAL NOTES AND SPECIFICATION DATA
-ITEMS 1128-1129- CONT'D
PERTAINING TO THE ITEMS "EXCAVATION" AND "EMBANKMENT".
-ITEM 1129-
The tolerances as outlined under Article 1129.3, Section 5 for density 7 test will be allowed.
Existing pavement shall be incorporated into the embankment unless otherwise directed by the engineer.
-ITEM 6350-
Temporary flexible reflective roadway marker tabs (TF-RRMT) shall be applied in a manner that will allow easy and complete removal leaving no conflicting marks to the satisfaction of the engineer.
The contractor shall maintain the TF-RRMT as long as they are required for traffic operations through the construction area.
TF-RRMT which, in the opinion of the engineer, fail to meet the requirements of this specification shall be replaced as directed by the engineer at the sole expense of the contractor.
-ITEM 6570-
Refer to "Standard Highway Sign Designs for Texas" for dimensions of any signs not described in the plans and specifications.
-ITEM 8027-
The flowable backfill will be placed in a minimum of two lifts.
Before placement of the flowable backfill, the contractor shall place blocking to maintain the grade and line of the corrugated metal pipe. The method of blocking shall be in a manner acceptable to the engineer.
The contractor shall provide acceptable openings in the deck of the existing structure to place the flowable backfill. Sufficient number of flagmen and traffic control devices will be provided to handle traffic through the work area.
The contractor shall assure watertight joints on the corrugated metal pipe prior to placement of the flowable backfill.

SPECIFICATION DATA
Sheet G =
## DISTRICT CONTACT PERSONNEL

<table>
<thead>
<tr>
<th>Category</th>
<th>Name</th>
<th>Title</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Information</td>
<td>B. R. Lindley, P. E.</td>
<td>Assistant District Engineer</td>
<td>(915) 676-6803</td>
</tr>
<tr>
<td></td>
<td>Blair Haynie, P. E.</td>
<td>Resident Engineer</td>
<td>(915) 676-6930</td>
</tr>
<tr>
<td></td>
<td>Roy Roberson, P.E.</td>
<td>Construction Engineer</td>
<td>(915) 676-6895</td>
</tr>
<tr>
<td></td>
<td>Glen Bohannan,</td>
<td>Construction Manager</td>
<td>(915) 676-6890</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flowable Fill</td>
<td>B. R. Lindley, P.E.</td>
<td>Assistant District Engineer</td>
<td>(915) 676-6803</td>
</tr>
<tr>
<td></td>
<td>Bob Satterwhite,</td>
<td>District Laboratory</td>
<td>(915) 676-6892</td>
</tr>
<tr>
<td></td>
<td>Buck Whitehead,</td>
<td>District Laboratory</td>
<td>(915) 676-6894</td>
</tr>
</tbody>
</table>
FIGURE 8: Test for Proper Consistency
FIGURE 9: Completed Structure